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The title of my talk this evening is "Structural Unemployment in Planetary Science". It might also be called "An Iconoclast's View of Our Situation as Planetary Scientists".

Classical examples of structural unemployment are the buggy industry and the buggy-whip industry. Another is the slide rule factory. More current examples are the steel industry and the nuclear reactor industry in the United States. In each of these cases there has been a basic structural change in the overall situation that has diminished the importance of certain lines of work.

I continue to be optimistic, in the long term, about planetary science because it has the fundamental durability of an intellectual endeavor and not the fragility of an economic one. But we have already lost a significant amount of political and exploratory passion. Such passion will not be easy to regain. All of this, ironically enough, is in the context of the spectacular successes of our planetary work during the past two decades.

I realize that talks in the mellow after-glow of a good dinner are expected to be inspirational and uplifting.

But I feel compelled to call the situation as I see it.

Let me first develop the background of my perception. This perception results from an attempt to cope with the deep-seated clash or competition between the realities and the mythology of space flight — under conditions of the past ten years, during which we have been engaged in what can be described accurately as a "zero-sum game".

Both the realities and the mythology have venerable foundations in human history.

The realities comprise scientific work and the many utilitarian applications of space technology. The most noteworthy of the latter is telecommunication, the only element of space technology that has thus far achieved a free-standing commercial status. All of the other great applications in navigation, surveillance, reconnaissance, meteorology, geodesy, and earth resources remain in the area of government services.

One of the all-time heroes of every physicist, astronomer, and engineer is the Englishman, Sir Isaac Newton, whose life spanned the years 1643-1727.

Among other achievements, he reduced the theory of motion to three simple, elegant, and all-encompassing principles, long called Newton's Three Laws of Motion. In the process of applying

these laws to the orbital motions of the moon and the planets, he discovered the Universal Law of Gravitation, one of the most profound facts of nature. He then gave a full explication of Kepler's empirical laws of the motion of the planets and finally put to rest the classical, quasi-religious controversy between the Ptolemaic and Copernician hypotheses of such motion.

The first edition of Newton's great treatise "Philosophiae Naturalis Principia Mathematica" was published under the imprimatur of Samuel Pepys in 1687. In this treatise he gave a thorough account of the principles of propelling objects into durable orbits around the earth and included a still-famous diagram on how to do this.

Several years ago, my wife and I visited the library of Trinity College in Cambridge, England and had the unforgettable experience of viewing Newton's personal copy of the first edition of the Principia, with his handwritten annotations (in Latin) in the margins. These annotations were incorporated as revisions in the second edition. Thus it is that our understanding of the principles of space flight dates from the second half of the 17th century.

Our tradition as scientists is to regard Newton and his many worthy predecessors and successors as the individuals in history who were really made of the "right stuff".

Let me now turn to the mythology of space flight.

For many centuries ignorance of physical principles has not restrained speculation on space flight. Nor does it today.

In 160 A.D., long before the time of Newton, the Greek satirist Lucian of Samosata wrote an account of how Ulysses' ship had been caught up in a tornado and carried on a seven day flight to the moon. In the early 17th century this work was translated from Greek into Latin by Johannes Kepler, the great planetary astronomer, in order to make it available to a wider audience. Soon thereafter, Kepler himself wrote a fantasy of space flight called "Somnium" (The Dream). In a 1629 letter to a friend he wrote:

> "If in the end we be driven from the earth, my book will serve as a useful guide for the emigrants and pilgrims who will be settling on the moon."

But Kepler was careful to make clear the speculative nature of his "dream".

During the subsequent three centuries, many other authors wrote accounts of voyages from the earth to the moon and of visits to the earth of extraterrestrial beings from the star Sirius and from Mars. The writings of Jules Verne and H. G. Wells are among the best known of these. Some of you may recall that in the early 1950's, Collier's Magazine published a series of illustrated articles by the rocket engineer Wernher von Braun and the

astronomer Fred L. Whipple. These articles depicted and described huge space stations with all of the amenities of a small city carrying large numbers of people in orbits around the earth. They also depicted permanent, manned bases on the moon and on the planet Mars.

The authors of these articles were thoroughly familiar with physical principles and were meticulous in not violating them. The conjectural element lay in the scale of their plans and the magnitude of the effort required to accomplish them.

Speculation on space flight is a booming trade in the entertainment industry at the present time and, for the most part, no attention whatever is given to either principles or practicality. Recent, well-known examples are the motion pictures "Star Wars" and "E. T." (for extraterrestrial). The American public has, so far, spent over 500 million dollars to see "Star Wars", about the sum required to actually accomplish a major planetary mission. I understand that the "Return of the Jedi" is doing even better. I draw no moral conclusions from these facts but I do consider them a point of reference on contemporary cultural values.

Closely akin to science fiction and also a prominent part of the 1983 scene are a large number of other, far ranging proposals for space flight. I may mention a few by short title:

Solar Power Satellites; Manufacturing in Space; Space Stations in Earth Orbit, on the Moon and on Mars; Military Installations on the Moon; the Economic Mining of Asteroids; and manned Missions to other stellar systems.

I am not so foolish as to suggest that such undertakings are totally out-of-the-question at some remote time in the future. But no one of them withstands critical scrutiny in the context of the present century and may never withstand a cost-to-benefit-ratio analysis. I consider that untimely advocacy of them, especially by prominent national figures, does the entire space effort a disservice. I may comment that I have no difficulty whatever in thinking up a billion dollar space project before breakfast, any day of the week, or a two billion dollar project on Sunday. But usually I spare my colleagues the pleasure of hearing them.

Nonetheless, undertakings such as I have listed above do have a certain popular and congressional appeal and some of them manage to make their way through the budgeting process of our federal government to appear as actual programs of work.

The thesis that space is one of the natural habitats of human beings is a prevalent one in some quarters. It sails under the slogan — "man's permanent presence in space." This slogan has a certain mystical or quasi-religious appeal. Every loyal

employee of NASA rises in the morning, faces east, bows three times, and repeats each time, "I believe in man's permanent presence in space." Thus refreshed, he goes off to work. This daily reaffirmation of faith is kindred to the belief in Heaven, a belief that may give one a certain amount of comfort in difficult times but lacks a persuasive, empirical foundation.

Some thirty years ago during the early development of the flight of large balloons and of manned balloon flight, there were advocates of the idea that a large network of manned balloons should be maintained and continuously replenished for the purpose of visual observation of natural and artificial activities on the earth. The classical comment on this idea was made by Ed Ney, one of the true pioneers in ballooning for scientific purposes. Ed had given a public lecture on some of his work in the late 1950's. In the subsequent discussion period, a woman in the front row stood up to ask a question. "Professor Ney, please tell me: Is there anything that a man can do in a balloon gondola that an instrument can not do?" Ed's answer, after only a moment's hesitation, was: "Yes, madam. Yes, there is. But why would anyone wish to do it at such a high altitude?"

The Landsat technique has clearly supplanted the idea that man's permanent presence at an altitude of 80,000 ft. is significantly useful.

I believe that the message can be generalized.

Ney's response represents my basic position on the matter of man's permanent presence in space. Even advocates of man's permanent presence in space are nowadays hard-pressed to think of rational bases for their belief and most are willing to admit that much of the public passion for the space flight of humans was drained away at the conclusion of the Apollo program. Apart from a major disaster in space, one must peer deeply into the murky future to imagine a revival of widespread and sustained public interest in such activities.

Next I wish to say a few words on what is commonly called the "coat-tail effect". The relevant assertion is that the entire space science program would be either non-existent or on a very small scale if it were not for the manned program. I consider that this assertion is impossible to either prove or disprove in a conclusive way, because we are unable to rerun history with different boundary conditions. But I can offer some reasons for doubting it.

First of all, beginning in 1945, we had a vigorous and successful program of high altitude rocket flights of scientific instruments. This work received a great impetus during the 1957-58 International Geophysical Year. It formed the basis, both technically and scientifically, for our subsequent enormous

advances in the use of satellites of the earth and interplanetary and planetary spacecraft for scientific and utilitarian purposes. The major growth of this work occurred simultaneously with the Apollo program under the leadership of Jim Webb as NASA administrator, a lawyer (not a scientist or engineer) and a consummate politician of broad vision. In my view, neither class of activity depended on the other to any important extent. Both occurred in an expansionistic epoch in national and international history. They occurred concurrently but interdependence is not obvious. All sorts of scientific and other activities of an unrelated nature also flourished during this epoch.

In further support of my skepticism, I may refer to what I believe to be a much more persuasive example of the "anti-coat-tail effect". This example is NASA's intended massacre of space science and planetary science, in particular, during the summer of 1981, an occasion well known to members of the DPS. It is much more plausible to attribute this potential disaster to the shuttle program than it is to attribute the growth of space science to the Apollo program. Thoughtful consideration of the summer of 1981 reveals, I believe, the true nature of NASA, as it has evolved over its 25-year history, in a way that nothing else does — namely its behavior in a crunch. In brief, mythology defeated reality.

I was reminded of a quotation that I have carried on one of my memory discs for some years: "Excessive devotion to the vaguely perceived future results in gross neglect of the present."

In the face of all of the great successes and future promise of solar system exploration, our federal government proposed, in the summer of 1981, to effectively terminate the entire enterprise — by eliminating support for existing solar system missions, cancelling missions already in an advanced state of development, indefinitely postponing all prospective missions, terminating support for theoretical and analytical work, and deferring the orderly planning of future missions.

The prospective U. S. termination of solar system exploration as well as many other fields of scientific investigation and many advanced applications of space technology was greeted by shocked disbelief by the scientific community of our own and other countries.

In most walks of life it is axiomatic that success breeds success. But I was compelled to remark that the federal government appears to regard the success of an undertaking as cause for its premature termination, whereas failure of an undertaking, as with many of our social programs, is cause for its expansion. Meanwhile, the Soviet Union, the European Space Agency, Japan, and other individual countries are

proceeding with solar system missions in a measured way with integrity of purpose.

The obvious villian in these distressing developments, about two years ago, was our national commitment to the development of the manned Space Transportation System, of which the shuttle is visualized as only the first step. This was my conclusion, as well as the conclusion of many of my colleagues. On my part, it was a reluctant conclusion because of my high professional regard for the individuals who are engaged in this great technical undertaking. Nonetheless, it remains my thoughtful conclusion in the arena of national policy.

In fairness, I will mention the other main elements of our predicament. In the euphoria of the post-Apollo epoch, national planning for space activities assumed that there would be a progressively increasing level of support such that the continuation of vigorous programs of manned flight and of advanced scientific and applicational missions would be possible. I am among those who consider that the United States can afford such a threefold undertaking, with balanced emphasis on its three basic elements.

But within the prevailing economic and political climate of the United States, the 1972 assumption of progressive, real growth in our space activities has proved to be false.

Furthermore, scientific and applicational missions have, under the same false assumption, been made progressively more sophisticated and much more expensive. The most conspicuous current examples are the Space Telescope and the Galileo mission to Jupiter, both of which are undertakings of great scientific promise but they are only part of the total picture.

The combination of all of these factors has led to our present distressed state.

Despite all of the above, we have been able to achieve a partial recovery from the despair of the summer of 1981, largely attributable to the efforts of members of the DPS and to sympathetic response of the Congress.

As of 1983, we have much to look forward to. Support for theoretical and analytical work has been partially restored. The infrared observatory at Mauna Kea is, at least temporarily, off the hit list. The McDonald committee of NASA headquarters is developing a program for reviving space science within the universities of the United States. Recommendations of the Solar System Exploration Committee are being given serious consideration.

Meanwhile, the existing ISEE-3 spacecraft is being maneuvered in flight so that it will fly through the coma of comet Giacobini-Zinner in 1985. This mission is a considerable retreat from our earlier plan to fly through comet Halley and rendezvous with comet Tempel II but is nonetheless a worthy

mission to a new type of astronomical object. Detailed planning for a scaled down version of the long planned and then cancelled Venus Orbiting Imaging Radar spacecraft, now called the Venus Radar Mapper, has been recently authorized and funded.

Continuing support for the brilliantly successful and on-going missions of Pioneer Venus orbiter, Pioneer 10, Pioneer 11, Voyager 1, and Voyager 2 is now moderately secure. Their further successes and, in particular, the prospective encounters of Voyager 2 with Uranus in January 1986 and with Neptune in August 1989 must be counted as bright spots in our professional outlook. The saga of the Galileo probe-orbiter mission to Jupiter outdoes the "Perils of Pauline". The originally planned launch date was January 1983. We are now thinking in terms of a May 1986 launch but many uncertainties — especially with respect to the launching system — still overhang the scene.

In the language of the banking industry, I believe that it is fair to say that the credit (or credibility) rating of planetary science continues to be at least a B+. We have consistently delivered on our promises and have usually exceeded them.

Nonetheless, our basic predicament remains. About two-thirds of the efforts of NASA are devoted to manned space flight. These efforts involve bringing the shuttle to a truly operational state

and undertaking the long-sought program for developing a system of space station — all for rather vaguely defined purposes.

As I remarked at our meeting last night, I give both of these enterprises a credibility rating of C-, a rather generous rating, I think.

I conclude by noting that living a long time can yield one a certain bouyant sense-of-humor about his own views and about life in general — as the only alternative to deep depression. In this vein, I wish to read a poem by Bert Leston Taylor. This poem is entitled "Canopus", one of the favorite reference stars of spacecraft engineers. In a certain sense, it summarizes my talk.

CANOPUS

When quacks with pills political would dope us,
    When politics absorbs the livelong day,
I like to think about the star Canopus,
    So far, so far away.

Greatest of visioned suns, they say who list 'em,
    To weigh it, science almost must despair.
Its shell would hold our whole dinged solar system,
    Nor even know 'twas there.

When temporary chairmen utter speeches,
    And frenzied henchmen howl their battle hymns,
My thoughts float out across the cosmic reaches
    To where Canopus swims.

When men are calling names and making faces,
    And all the world's ajangle and ajar,
I meditate on interstellar spaces,
    And smoke a mild seegar.

For after one has had about a week of
    The argument of friends as well as foes,
A star that has no parallax to speak of
    Conduces to repose.

-- Bert Leston Taylor (1866-1921)
Chicago journalist, novelist, and verse writer